

⑩ 日本国特許庁(JP)

⑪ 特許出願公開

⑫ 公開特許公報(A) 平1-282362

⑬ Int. Cl.

識別記号

庁内整理番号

⑭ 公開 平成1年(1989)11月14日

D 02 J 1/18

Z-6936-4L

審査請求 未請求 請求項の数 2 (全4頁)

⑮ 発明の名称 炭素繊維束の開繊方法

⑯ 特 願 昭63-110435

⑰ 出 願 昭63(1988)5月9日

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明 細 書

1. 発明の名称

炭素繊維束の開繊方法

2. 特許請求の範囲

1. 引き揃えた炭素繊維束を超音波により軸方向に振動している丸棒の少なくとも2本以上に順次接触通過させることを特徴とする炭素繊維束の開繊方法。

2. 引き揃えた炭素繊維束を超音波により軸方向に振動している丸棒の少なくとも2本以上に順次接触通過させると共に、通過の途中でガス流を吹き付けることを特徴とする炭素繊維束の開繊方法。

3. 発明の詳細な説明

〔産業上の利用分野〕

本発明は炭素繊維束を均一に薄く開繊する方法に関する。

〔従来技術および発明が解決しようとする課題〕

近年単一材料では得られない高比強度、高比弾性率を有する炭素繊維強化複合材料が脚光を浴び

その利用分野が大きく広がっている。

例えば、炭素繊維束を一方向に引き揃え、エポキシ等の熱硬化性樹脂で含浸したプリプレグは釣り竿、ゴルフシャフトなどのスポーツ用品に幅広く利用されている。さらにX線テーブルなどの医療機器、あるいは航空機材料へと用途は拡大の一途をたどっている。

この用途の拡大に伴い複雑な曲面形状などにも高い成形性を有するドレープ性の良好な極薄タイプのプリプレグへのニーズが高まっている。

極薄タイプのプリプレグの製造は炭素繊維束をいかに薄く均一に広げるか、すなわち開繊技術に大きく依存しており、その技術の開発が望まれている。

従来、炭素繊維束を開繊する方法としては、

①丸棒しごきによる方法(特開昭 60-9981号公報)、

②水流による方法(特開昭 52-151362号公報)、

③空気流による方法(特開昭 57-71342号公報)、

④丸棒を横振動させる方法(特開昭 56-43435号

⑤ 空気流による方法では、炭素繊維束中のフィラメント同士の結束を解いて十分な開張効果を得るには比較的高圧で大流量の空気が必要で、そのため炭素繊維の毛羽立ちが生じ、それが飛散し腐

超音波の作用により丸棒 2 に軸方向の振動を与える方法としては特に限定されず公知の方法が用いられる。例えば第 1 図のように公知の超音波発

本発明者らは従来のものつ課題を解決すべく、
 点検時を要した結果、軸方向に超音波で振動する
 丸棒に炭素繊維束を接触通過させること、あるい
 はそれにガス流を併用することによりついに上記
 課題を解決できることを見だし本発明に至った。
 すなわち本発明は、

前述の周波数、振幅の範囲内であれば炭素繊維束にかかる張力を安定的に制御することが容易で、炭素繊維束は作行することがない。

超音波振動を与えた丸棒に炭素繊維束を振動方向に直角に接触通過させることが望ましいがとくに限定されない。また炭素繊維束 1本当りの丸棒との接触面積は炭素繊維束の丸棒通過前後の角度によって増減するが、本発明では接触面積をとくに限定するものではない。接触面積を大きくすると開繊効果が大きくなる傾向にあり、丸棒が少なくても、非常に損傷の受けやすい高弾性炭素繊維束を開繊する場合は丸棒 1本当りの接触面積を少なくし、丸棒の本数を増加させて接触回数を増やすことが望ましい。

本発明では超音波で振動している丸棒を少なくとも 2本以上使用し接触回数を 2回以上とすることが必要である。即ち丸棒を軸方向に超音波で振動させる場合、通常振動しない部分と最大振幅をとる部分が半波長の周期で存在するので丸棒を 1本しか使用しない場合には均一な開繊結果を得ることができない。また最大振幅の部分で接触通過させた炭素繊維束の場合も 1回の接触では十分な開繊結果を得ることができないので炭素繊維束の

張力を大きくする必要があり炭素繊維が損傷しやすくなる。

接触回数を 2回以上、好ましくは 3～5回とすることにより炭素繊維束に大きな張力を付加することなく均一な開繊効果を得ることができることを見いだされた。この場合、丸棒の使用本数に応じて個々の丸棒の振動の位相が炭素繊維束の通過方向に対しずれるように配置することが好ましい。

各丸棒に作用させる超音波の周波数はそれぞれ同じでも違っていてもかまわないが、同じであることが好ましい。また各丸棒の間隔は特に限定されず、当業者が任意に決定し得るものである。

さらに、この超音波で振動する丸棒を接触通過している炭素繊維束に、その通過の途中においてガス流を吹き付けることにより、一層大きな開繊効果を得ることができる。また超音波のみに比較して、丸棒の使用本数を減少させることも可能である。

ガス流を吹き付ける箇所は特に制限されず、炭素繊維束が丸棒と接触する際、あるいは各丸棒と

丸棒の間、またはその両方において吹き付けることができる。この場合、ガス流は前記箇所の 1箇所において吹き付けることにより、優れた開繊効果を得ることができるが、2箇所以上において吹き付けることにより、一層の開繊効果が得られる。

ガス流は特に制限されるものではないが、空気流を用いるのが好ましい。

ガス流の流量、圧力は特に限定するものではない。圧力については $0.01 \sim 10 \text{ kg/cm}^2$ が一般的であるが、 $0.1 \sim 5 \text{ kg/cm}^2$ が特に好ましい。 0.01 kg/cm^2 より小さいと開繊効果が小さく、 10 kg/cm^2 より大きいと炭素繊維束の張力が過大となり、炭素繊維束の損傷の原因となる。流量については $1000 \text{ フィラメント当り } 0.01 \sim 50 \text{ l/min}$ が好ましく、特に $0.1 \sim 30 \text{ l/min}$ が好ましい。 0.01 l/min より少ないと開繊効果が小さく、 50 l/min より多いと目割れを生じ、均一な開繊が得られない。

本発明においては、超音波により振動している丸棒の作用により、炭素繊維束中のフィラメント同士の結束が厚けており、またすでに開繊してい

るので、吹き付けるガス流は低圧力、低流量で十分な効果を得ることができる。

吹き付ける方向も丸棒に対し垂直であることが特に好ましいが、炭素繊維束に対しては平行でも垂直でもよく、特に制限はない。吹き付ける方向が丸棒に垂直でない場合は炭素繊維束の位置がずれるなど不安定になるので好ましくない。

【発明の効果】

以上の本発明の方法により、毛羽等の発生、飛散等の問題がなく、滑く均一な炭素繊維束の開繊を容易に得ることができる。

【実施例】

以下、本発明を実施例に基づき具体的に説明する。

実施例 1

1束 2000 フィラメント とからなりサイジング剤を除去したビッチ系炭素繊維束（日本石油製） 50 本 を 8 mm 間隔で平行に並べ、位相を $1/10 \text{ 波長}$ ずつずらしながら 20 mm 間隔で平行に並んでいる周波数 20 KHz 、振幅 $10 \mu\text{m}$ で軸方向に超音波を作

用させることにより振動している径30mmの丸棒3本に接触通過させた。

この結果、互いに隣接する炭素繊維束の間の隙間は無く均一に閉鎖されていた。

実施例2

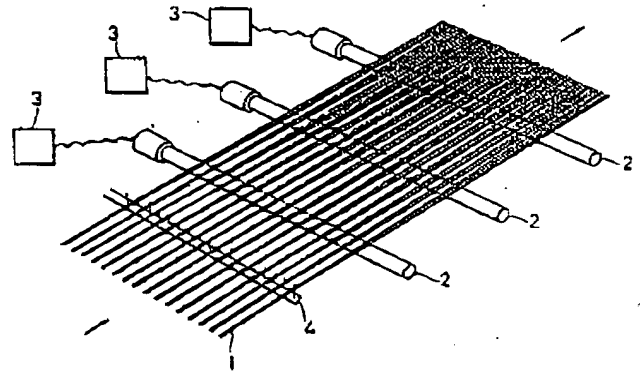
実施例1と同じ装置でサイジングを除去した1束8000フィラメントからなるビッチ系炭素繊維束(日本石油精製)20本を25mm間隔で平行に並べ、実施例1と同様の方法で、丸棒5本に接触通過させつつ、2段目、3段目、4段目の丸棒通過時にそれぞれ圧力1.0kg/cm²、炭素繊維束1束当たり5.0l/minの流量の空気中を穴のあいたパイプを通して丸棒に直角に吹き付けた。この結果、互いに隣接する炭素繊維束の間の隙間は無く均一に閉鎖されていた。

4. 図面の簡単な説明

第1図は本発明の一実施態様を示す概念図である。

- | | |
|------------|----------|
| 1…炭素繊維束、 | 2…閉鎖用丸棒、 |
| 3…超音波発生装置、 | 4…くし。 |

第1図



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(English Translation of Japanese Patent Application Laid-open No.1-282362)

Method of spreading a carbon fibers bundle

WHAT IS CLAIMED IS:

1. Method of spreading a carbon fibers bundle wherein respective carbon fibers bundles aligned side by side are passed through two or more circular rods ultrasonically vibrating in their axial direction one after another.
2. Method of spreading a carbon fibers bundle wherein respective carbon fibers bundles aligned side by side are passed through two or more circular rods ultrasonically vibrating in their axial direction one after another and a gaseous fluid is blown over to said bundles in passage.

DETAILED DESCRIPTION OF THE INVENTION

(TECHNICAL FIELD)

The invention relates to a method of uniformly and thinly spreading a carbon fibers bundle.

(PRIOR ART AND ISSUES TO BE SOLVED)

In recent years, a carbon fibers reinforced complex material is popular because of its higher strength and elastic modulus than a material made from the sole component, resulting in the use of such complex material being expanded in various fields.

Such pre-impregnation sheet as its respective carbon filaments bundles being uni-directionally aligned with each other and impregnated with such thermoset resin as epoxy resin, for instances, is widely adopted for the material of such sports and leisure items as a fishing rod, a golf shaft and so forth. Its use is further expanded into such medical appliances as an X-ray table and aerospace industry.

In accordance with such expansion of its use in various fields, an extremely thin pre-impregnation sheet good at drape property or fittable into a complicated curvature configuration is sought after.

Whether such extremely thin pre-impregnation sheet is successfully produced or not depends upon a method of uniformly

and thinly spreading a carbon fibers bundle, which improvement is anxiously hoped for.

Conventionally, the following methods are known for spreading a carbon fibers bundle.

Namely, (1) a method of spreading the same by rubbing it with a circular rod is disclosed in Japanese Patent Application Laid-open No.60-9961.

(2) A method of spreading the same with water flow is disclosed in Japanese Patent Application Laid-open No.52-151362.

(3) A method of spreading the same with air flow is disclosed in Japanese Patent Application Laid-open No.57-77342.

(4) A method of spreading the same by vibrating a roller in its axial direction is disclosed in Japanese Patent Application Laid-open No.56-43435.

The above method (1) requires that the tensile force applied to the bundle be large in order to widely spread the bundle comprising 3000 filaments into a sheet of 5 mm or more, to which bundle the tensile force in the order of 1.5kg is applied, which results in doing damage on the bundle and causing fluffs and fibrous cut on the surface. Once the fluffs are entangled around the circular rod, the carbon fibers bundle is vulnerable to further damage that prevents the bundle from being continuously spread. On the other hand, provided that the tensile force applied to the bundle is lowered in order to avoid such fibrous damage, a problem occurs in which the bundle is not spread enough to be formed into a sheet.

The above method (2) is faced with a problem in which the bundle is not uniformly spread and the spread filaments are bundled again by the action of surface tension after taken out of the water. Further, unfavorably, this method requires additional equipment or higher energy consumption for drying up the sheet in wet condition.

The above method (3) requires a large volume of high-pressurized air in order to bring spreading operation in

which the bonding between the respective filaments is untied into effect, which raises fluffs on the fibrous surface, which fluffs causing short-circuits on the electrical devices concerned so that this method is problematic in the safety aspect of the operation. Further, the bundle is hard to be uniformly spread in the same way as the above (2).

As for the above method (4) with a low frequency ranging from 5 to 10Hz and a length ranging from 1 to 10 mm by which the roller vibrates in its axial direction, such length is remarkably large in comparison with the diameter of the filament so that the tensile force applied thereto fluctuates to large extent. Thus, the carbon fibers are more vulnerable to damage than the above method (1). Further, the carbon fibers bundle is liable to undulate.

(MEANS TO SOLVE THE ISSUES)

In view of the foregoing inconveniences encountered with the prior art, the present inventors solve the above issues by passing the carbon fibers bundle through and in contact with the rods ultrasonically vibrating in their axial direction along with subjecting the bundle in passage to a gaseous fluid flow.

That is to say, the invention relates to (1) a method of spreading a carbon fibers bundle characterized in passing the respective bundles aligned side by side through and in contact with two or more rods ultrasonically vibrating in their axial direction one after another and to (2) a method of spreading a carbon fibers bundle characterized in passing the respective bundles aligned side by side through and in contact with two or more rods ultrasonically vibrating in their axial direction and blowing a gaseous fluid over to the respective bundles in passage.

Hereafter, the invention is described with reference to Figure 1.

Figure 1 is a view to show one example of the invention, in which reference numerals 1, 2, 3 and 4 respectively indicates a carbon fibers bundle, a circular rod, an ultrasonic oscillator

and a comb.

As shown, the respective bundles 1 unwound from the creel are aligned side by side by the comb 4 and spread while passing through and in contact with two or more rods 2 ultrasonically vibrating in their axial direction one after another.

The way by which vibration is ultrasonically given to the axial direction of the respective rods is not specified herein, but may well be that conventionally known. For instance, preferably, an ultrasonic oscillator 3 as shown in Figure 1 is put to use.

Preferably, the respective rods ultrasonically vibrate in their axial direction only, and the vibration in the crosswise direction with regard to the axial direction is not applied. This is due to the fact that the application of the vibration crosswise with regard to the axial direction fluctuates the tensile force applied to the respective filaments comprising the respective bundles so as to cause damage on the fibrous surface.

The ultrasonic vibration due to its higher frequency unties the bonding between the respective filaments instantly, whereby fine vibrations bring favorable spreading effect.

The frequency in use herein is preferably more than 15 KHz, more preferably, in the order of 15 to 500 KHz. The length by which the respective rods vibrate in their axial direction ranges from 2 to 500 μ m, more preferably, ranging from 5 to 50 μ m. Such length being lower than 2 μ m, the spreading effect is lowered while that being more than 500 μ m, the tensile force applied to the respective filaments of the bundle fluctuates so as to cause the fibrous damage.

The ultrasonic frequency and the length respectively being within the range as mentioned above, stably controlling the tensile force applied to the bundle becomes easier and there is no case where the bundle undulates.

It is preferable to pass the respective carbon fibers bundles through and crosswise in contact with the respective rods vibrating in their axial direction, to which the invention

is not limited. The contact area of the respective bundles with the respective rods is controlled by the contact angle of the respective bundles with regard to the respective rods before and after the former passing through the latter, which contact area is not specifically defined in this invention. Enlarging such contact area, spreading effect tends to become enhanced, which reduces the number of the rods in use. Where a high elastic modulus carbon fibers bundle highly vulnerable to damage is spread, it is preferred to reduce the contact area with the respective rods while to increase the number of the rods in use so as to increase the number of contacts.

It is required herein to use two or more circular rods ultrasonically vibrating in their axial direction so as to make the number of contacts two times or more. There exist a first part that does not vibrate and a second part that vibrates by the maximum length by a half-wavelength pitch in a circular rod ultrasonically vibrating in its axial direction. Thus, in the case where only one circular rod is put to use, the carbon fibers bundle is not uniformly spread. Further, even when the bundle is passed through and in contact with the second part, the bundle is not uniformly spread just with the sole contact with such second part, which makes it unavoidable to intensify the tensile force applied to the bundle, which results in vulnerably doing damage on the fibrous surface.

It is found herein that making the number of contacts two times or more, preferably, three times to five times enables the bundle to be uniformly spread without the necessity of applying a larger tensile force to the bundle. In this case, it is preferable to dispose the respective rods with their vibration phase displaced with regard to the moving course of the bundle according to the number of the rods in use.

The ultrasonic frequency with which the respective rods vibrate may vary, but more preferably, shall be the same. Further, the interval between the respective rods is not specifically defined herein, but may be decided by a person in the art in an arbitrary manner.

The carbon fibers bundle is by far more uniformly spread by blowing a gaseous fluid over the bundle in passage through and in contact with the rod ultrasonically vibrating in its axial direction. This enables the number of the rods in use to be reduced in comparison with the case where only the rods ultrasonically vibrating in their axial direction being used.

The point where the gaseous fluid is blown over to the bundle in passage is not specifically defined herein, but may be either that where the bundle in passage makes in contact with the respective rods or an in-between of the respective rods or both of them. Blowing such gaseous fluid over to the bundle at those two points is more effective for spreading the bundle than only at one of those points.

The gaseous fluid is not specifically defined herein, but the air flow is preferable.

Neither a flow rate at which the fluid flows nor a pressure applied to the bundle in passage is specifically defined herein. As for such pressure, it normally ranges from 0.01 to 10 Kg/cm², more preferably, ranging from 0.1 to 5 Kg/cm². Such pressure being smaller than 0.01 Kg/cm², spreading effect becomes poor while that being larger than 10Kg/cm², the tensile force applied to the bundle becomes too excessive, resulting in doing damage on the fibrous surface. As for such flow rate, it preferably ranges from 0.01l/minute to 50l/minute per 1000 filaments, more preferably, ranging from 0.1 to 30l/minute. Such flow rate being smaller than 0.01l/minute, spreading effect becomes poor while that being larger than 50l/minute, a gap occurs between the adjacent filaments of the respective spread bundles on account of the respective bundles being not uniformly spread.

A gaseous fluid at a lower flow rate or a lower pressure applied to the bundle in passage will do on account of the bonding between the respective filaments of the bundle being untied by the action of the respective rods ultrasonically vibrating in their axial direction.

The gaseous fluid is preferably blown over crosswise to the respective rods, but the direction in which such fluid is

blown over to the bundle may be either parallelwise or crosswise with regard to the bundle, which direction is not specifically defined in the invention. Where the fluid is not blown over crosswise with regard to the respective rods, the bundle is displaced in an unstable manner.

(EFFECT)

According to the invention, there is no case where fluffs occur on the fibrous surface or they scatter around and the carbon fibers bundle is uniformly and thinly spread with ease.

(EMBODIMENT)

EXAMPLE 1

Fifty carbon fibers bundles respectively comprising 2000 filaments marketed by Nihon Sekiyu Co., Ltd. with a sizing agent removed are aligned parallelwise with an interval of 8 mm between them, which bundles are passed through and in contact with three rods respectively of 30 mm in diameter ultrasonically vibrating over the length of 10μm in their axial direction with a frequency of 20 KHz and lined in parallel with an interval of 20 mm and a phase displaced by one-tenth wavelength between them.

Consequently, the respective bundles are uniformly spread without a gap between any adjacent filaments.

EXAMPLE 2

Twenty carbon fibers bundles respectively comprising 6000 filaments marketed by Nihon Sekiyu Co., Ltd. with a sizing agent removed are lined in parallel with an interval of 25 mm between them and passed through and in contact with five rods in the same way as the Example 1 in the meantime an air flow applying a pressure of 1.0 Kg/cm² to the respective bundles at a flow rate of 5.0l/minute is blown over crosswise with regard to the second, third and fourth rods through a bored pipe. Consequently, the respective bundles are uniformly spread without a gap between any adjacent filaments.

4. BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows one embodiment of the invention.